

Type Ibc supernovae in disturbed galaxies: evidence for a top-heavy IMF

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Abstract. We compare the radial locations of 178 core-collapse supernovae to the R -band and $H\alpha$ light distributions of their host galaxies. When the galaxies are split into ‘disturbed’ and ‘undisturbed’ categories, a striking difference emerges. The disturbed galaxies have a central excess of core-collapse supernovae, and this excess is almost completely dominated by supernovae of types Ib, Ic and Ib/c, whereas type II supernovae dominate in all other environments. The difference cannot easily be explained by metallicity or extinction effects, and thus we propose that this is direct evidence for a stellar initial mass function that is strongly weighted towards high mass stars, specifically in the central regions of disturbed galaxies.

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1. Introduction

Following the pioneering work of Larson & Tinsley (1978), many studies have confirmed that tidal disturbance following galaxy interactions is an efficient trigger of star formation in galaxies (e.g. Joseph et al., 1984; Kennicutt & Keel, 1984). Such star formation frequently takes the form of centrally-concentrated nuclear starbursts (Joseph & Wright, 1985), fuelled by the central concentrations of molecular gas found to occur naturally in simulations of highly-disturbed systems (Barnes & Hernquist, 1991; Mihos & Hernquist, 1996). The strength of the link between starbursts and interactions was highlighted by the finding that almost all of the ‘ultra-luminous infrared galaxies’ (ULIRGs) display signs of interactions or mergers (Sanders et al., 1988; Borne et al., 1999), and by correlations between galaxy-galaxy separations and starburst strength (Barton et al., 2000). Even minor mergers with low-mass companions have been shown through simulations to result in significant nuclear star formation activity (Mihos & Hernquist, 1994).

Several early studies of nuclear starbursts suggested that this star formation might require a top heavy initial mass function (IMF), preferentially producing high mass stars (Rieke et al., 1980; Doyon et al., 1992). There is theoretical support for this suggestion, with simulations showing that an IMF weighted to high-mass stars naturally arises in high-density regions, due to feedback processes heating the gas. In a recent study, Krumholz et al. (2010) have demonstrated that such regions should have a high-mass stellar fraction at least 1.7 times larger, and possibly much more, than lower density, more quiescent regions.

However, the observational evidence for this variation has to date proved controversial (see Bastian et al. 2010 for a recent review). Some studies have found indirect evidence for top-heavy IMFs with, for example, Rieke et al. (1993) concluding that the nearby starburst galaxy M82 requires an IMF biased to high mass stars to explain its emission line ratios and total luminosity. Similar techniques have been used for NGC 3256 (an ongoing merger with a ‘super-starburst’) which have again shown indications of a modified IMF with an excess of high mass stars (Doyon et al., 1994). Gibson & Matteucci (1997) showed that, in order to reproduce the observed colour-luminosity relation of elliptical galaxies, an IMF much flatter than that of Salpeter (1955) needed to be adopted. Baugh et al. (2005) had to employ a top heavy IMF for the starbursts powering the distant population of highly luminous submillimetre galaxies in order to explain the number counts of these systems. Finally, Brassington et al. (2007) studied nine interacting galaxies from the *Chandra* survey and found that highly disturbed systems showed a strongly enhanced infrared luminosity compared to that expected from the x-ray emission, again suggesting the need for a top-heavy IMF.

More direct evidence of a variation in IMF has been found for the resolved stellar population of the young Arches cluster in the Galactic Centre. Figer et al. (1999); Stolte et al. (2002); Paumard et al. (2006); Espinoza et al. (2009) all find evidence for stellar mass functions weighted towards high-mass stars in this cluster or the general

Galactic Centre region. Such mass functions are parametrized as an IMF that is either much flatter than that found by Salpeter (1955), or having a higher mass turnover than is found in the function for field stars.

One possible tracer of the IMF that has not been fully exploited to date is the relative numbers of core-collapse supernovae (CCSNe) of different types. Their short progenitor lifetimes and high luminosities make them powerful indicators of recent or ongoing star formation, and indeed they provide the only direct tracer of recent star formation within unresolved stellar populations. Recent advances in the understanding of supernovae and their progenitors raise the possibility that they can provide information on the initial mass function of a young stellar population. Theoretical models of single star progenitors predict that SNII should have lower mass progenitors than SNIb or SNIc (Heger et al., 2003; Eldridge & Tout, 2004). This has received observational support from studies of the strength of association with $H\alpha$ emission (Anderson & James, 2008), confirming that SNII have the lowest mass CC progenitors, but additionally indicating that the SNIc have still higher mass progenitors than the SNIb. The existence of this II-Ib-Ic progenitor mass sequence allows information on the IMF of the stellar population in the SN environments to be derived from the relative numbers of type II, Ib and Ic supernovae.

Petrosian & Turatto (1995) studied the distribution of SNe events in 32 interacting systems containing 12 known core collapse SNe. They found that the radial distribution of these core collapse events showed a higher concentration towards the nuclear regions of the interacting galaxies when compared to isolated galaxies. This confirmed the enhanced star formation around the central regions of the systems, but the sample was too small to analyse the separate types of CCSNe.

This paper will therefore use a larger sample of local CCSNe to explore the IMF in nuclear starbursts, resulting from galaxy disturbance, by studying the ratio of type II/Ibc SNe in both disturbed and undisturbed host galaxies. Throughout this paper, we use ‘Ibc’ to encompass all SNe with classifications of Ib, Ic or Ib/c.

The structure of the paper is as follows: In Section 2 we will define and discuss the sample used throughout this work. Section 3 will describe the results on the radial distributions, for disturbed and undisturbed hosts and looking separately at type II and Ibc SNe. In Section 4 we discuss the possible interpretations of our results, in terms of metallicity, extinction and IMF effects. Finally, Section 5 contains a summary of our conclusions.

2. Sample and observations

The sample used in this work consists of 140 local (recession velocity <6000 km/s) spiral galaxies, hosts to 178 CCSNe (110 SNII and 68 SNIbc), for which we have $H\alpha$ and R -band observations from the Liverpool Telescope (LT) and Isaac Newton Telescope (INT). (Some galaxies do not have usable images in either $H\alpha$ or R -band and have been omitted from the corresponding plots and statistics; see Tables 1 & 2 in the online

material). This is the same dataset as was used by Anderson & James (2009) with a small number of subsequent observations. SNe classified as type IIb are not included in this sample as they are thought to be transitional objects between SNII and SNIb, with substantially larger progenitor masses ($\sim 25 M_{\odot}$; Smartt 2009) than typical SNII. A comparison performed on January 21st 2010 with all CCSNe host galaxies within the same recession velocity limit in the IAU SN catalogue[‡], and where the SNe have accurate classifications and positions, showed this sample to be $\sim 34\%$ complete for SNIbc and $\sim 18\%$ complete for SNII.

The classification of host galaxies as disturbed is purely by visual inspection by the authors and thus is subjective. Galaxies which show signs of tidal tails, definite interaction, double nuclei or strong asymmetry have therefore been classed as disturbed.

3. Results

The total sample of CCSNe is dominated by SNII (62% of the total). When the sample is constrained only to supernovae which lie in disturbed hosts (64 CCSNe) this falls to 56% SNII, compared to 65% SNII in the non-disturbed hosts.

For each of the CCSNe in our sample we have calculated the $\text{Fr}(R)$ and $\text{Fr}(\text{H}\alpha)$ statistics used, and explained fully, in Anderson & James (2009). Briefly, these represent the fractions of galaxy emission, in the R -band and $\text{H}\alpha$ respectively, that lie within the circle or ellipse which contains the SN. Thus $\text{Fr}(R)=0.0$ corresponds to a supernova at the central R -band peak of the galaxy emission, or closer to this peak than any $\text{H}\alpha$ emission, in the case of $\text{Fr}(\text{H}\alpha)$; whilst $\text{Fr}=1.0$ implies an extreme outlying SN. If the emission is statistically a good tracer of the parent population of supernovae, the Fr values should have a flat distribution with a mean value of 0.5.

Figures 1 and 2 show the distributions of $\text{Fr}(R)$ values for the CCSNe in the present sample, for the undisturbed and disturbed galaxies respectively. In all histograms shown in this paper, the upper plot represents the CCSNe sample, the middle the type II SNe and the lower SNIbc. Looking first at the overall distributions of CCSNe, there is a clear difference between the disturbed and undisturbed subsets, in the sense that the disturbed galaxies have substantially more CCSNe occurring in their central regions, with low $\text{Fr}(R)$ values. For example, 36 of the 58 CCSNe in the disturbed sample occur within the central 50% of the R -band light, 62% of the total, compared with 50 out of 112 (45%) in the undisturbed galaxies. A Kolmogorov-Smirnov (KS) test shows that the chance of the two total CCSNe distributions being drawn from the same parent distribution is $P=0.037$. Thus there is evidence at the 2σ level that galaxy disturbance correlates with centrally-enhanced star formation and hence the production of an increased central fraction of CCSNe.

The most striking aspect of Figure 2 is the types of SNe that make up this central excess in the disturbed galaxies. Remarkably, given that SNIbc only comprise 38% of the overall CCSN sample (68/178), all 5 of the CCSNe coming from the central 10% of

[‡] <http://www.cfa.harvard.edu/iau/lists/Supernovae.html>

the disturbed host galaxy light, and 11 of the 13 coming from the central 20% of the light, are of type Ib/c. A KS test of the $\text{Fr}(R)$ distributions for the disturbed galaxy subsample finds $P=0.003$, indicating a very low probability that the SNIbc and SNII $\text{Fr}(R)$ values are drawn from the same parent distribution. The mean values of $\text{Fr}(R)$ are 0.31 (95% confidence limits 0.20–0.42) for the SNIbc in the disturbed galaxies, compared with 0.51 (0.44–0.59) for the SNII in the disturbed galaxies. This is the main observational result from this paper; the CCSNe occurring in the central regions of disturbed galaxies are heavily weighted towards types Ib, Ic and Ib/c. We will discuss possible interpretations of this in Section 4.

Some further statistical tests were also performed on the CCSN distributions shown in Figures 1 & 2. Figure 1 shows that even in the undisturbed galaxies, there is some evidence for a larger fraction of SNIbc in the central regions, principally due to a central ‘hole’ in the radial distribution of SNII. A KS test applied to the SNIbc and SNII distributions shown in Figure 1 shows this difference to be only marginal, $P=0.082$, and hence clearly less marked than for the disturbed galaxies; disturbance does seem to play a part in the central concentration of the SNIbc. This point was further explored by comparing the SNIbc distributions for undisturbed and disturbed galaxies, i.e. Figure 1 vs. Figure 2; this did indicate the SNIbc in disturbed galaxies to be more centrally concentrated, with a KS P value of 0.06, again of marginal significance. The mean SNIbc $\text{Fr}(R)$ value is 0.48 (0.38–0.57) for the SNIbc in the undisturbed galaxies, again to be compared with 0.31 (0.20–0.42) already quoted for the disturbed galaxies. Finally for Figure 2, it might be asked whether there is evidence for a *suppression* of SNIbc fraction in the outer regions of these galaxies. However, given the current sample size this cannot be determined with any significance. For example we find 6 SNIbc in the outer 50% of the light distributions of the disturbed galaxies, but with only 22 CCSNe in total from these regions, this is not significantly below the expectation value of 8.4, based on the SNIbc/SNII ratio for the full sample.

Figures 3 & 4 show the distributions of supernova locations relative to the $\text{H}\alpha$ distributions of their host galaxies. Overall these show the same patterns as Figures 1 & 2, but they do enable one specific issue to be addressed: are the SNIbc more centrally concentrated than the $\text{H}\alpha$ light, which is presumably a good tracer of the youngest stellar population? Figure 4 shows that there is some evidence for this; the central 10% of the $\text{H}\alpha$ emission in the disturbed galaxies gives rise to 7 of the 22 SNIbc in these galaxies. The mean $\text{Fr}(\text{H}\alpha)$ value for the SNIbc in disturbed galaxies is 0.33 (0.21–0.45), so this population does seem to be more centrally concentrated than the $\text{H}\alpha$ emission. This is not true for the SNIbc in the undisturbed galaxies, or for the SNII in either of the galaxy subsets; all of these distributions have mean $\text{Fr}(\text{H}\alpha)$ values consistent with 0.5.

4. Discussion

Anderson & James (2009) found a central excess of SNIbc in a SN-host galaxy sample.

This work has found that this central excess is exaggerated in galaxies which appear disturbed. A more centrally located distribution of SNIbc has been suggested previously (e.g. Bartunov et al., 1992; Petrosian & Turatto, 1995; van den Bergh, 1997), though previous studies often suffered from low number statistics. Hakobyan et al. (2009) also find SNIbc to be more centrally located than SNII, however in conflict to our results they do not find the central excess of SNIbc clearly seen in our data. An important difference between our work and most other studies in the literature is that our method implicitly normalizes the tests to the measured distributions of different stellar populations; other studies use distances normalized to isophotal radii. Most of these results have been interpreted as an increase in metallicity of the SNIbc progenitors, although Hakobyan et al. (2009) also make the suggestion of a shallower IMF within the central regions.

Studies conducted into active and star-forming galaxies (Petrosian et al., 2005) and Seyfert galaxies (Bressan et al., 2002) have also noted marginal evidence for an increased fraction of both CCSNe and specifically SNIbc within these galaxies when compared to ‘normal’ ones.

There are various observational biases which may affect our analysis. Shaw (1979) found a bias in supernova samples, in the sense that it is more difficult to detect SNe in the inner regions of distant galaxies. The sample is also subject to any bias contained within the object selection found in the Asiago (Barbon et al., 2009) and IAU SN catalogues. For the Asiago and Crimea searches, Cappellaro et al. (1993) estimated the number of SNe lost due to overexposure combined with the Shaw effect, which for the velocity range of our sample is $\sim 35\%$. Another source of bias is the loss of SNe in the central regions of galaxies through the large amount of dust obscuration which has been investigated through near infrared studies (e.g. Mattila et al., 2007; Kankare et al., 2008). Such biases should affect all SN types, although the intrinsically fainter SNIIP (Richardson et al., 2002, 2006) may be rather more likely to be lost through these effects. However, if our results are correct and SNIbc are more centrally concentrated than SNII then recovering all of the lost central SNe would lead to an even more exaggerated excess.

One possible source of error is our eyeball classifications of host galaxy disturbance. In future we plan to quantify this through near-IR observations and use of objective measures of asymmetry (Conselice et al., 2000; Lotz et al., 2004). However, we are quite confident in our disturbance classifications; images of 12 of our ‘disturbed’ galaxies with centrally-located SNe are shown in Figure 5, confirming that this is not a ‘normal’ group of galaxies.

The high central excess of SNIbc in the central regions of the disturbed host galaxies found in this work is difficult to explain in terms of effects other than an IMF biased towards high-mass stars. A possible alternative explanation is the effect of metallicity, given that Boissier & Prantzos (2009) find that the ratio of SNIbc/SNII increases with both local and global metallicity. Looking at the absolute magnitudes of the host galaxies, we do indeed find that the disturbed galaxies are somewhat more luminous

than the undisturbed galaxies (KS probability of 0.07 that they are drawn from the same parent distribution), by almost 0.4 mag in the mean, which might imply a somewhat higher mean metallicity in the disturbed galaxies. However, this does not seem to be driving the result we find. Splitting the total sample (disturbed and undisturbed) by absolute magnitude, we find no significant differences in the $\text{Fr}(R)$ distributions of bright and faint galaxies. Splitting into bright and faint halves, the KS probability is 0.998 (complete consistency), whereas when the bright third is compared with the faintest two-thirds (to better match the disturbed/undisturbed split), P is 0.276, but in the sense that the bright galaxies have a slight bias towards *high* $\text{Fr}(R)$ values. In any case, the expected metallicity bias resulting from a difference of 0.4 in galaxy absolute magnitude is very small. The mass-metallicity relation of Tremonti et al. (2004) for galaxies of a few times $10^{10} M_{\odot}$ predicts a corresponding change of only ~ 0.025 dex in $\log(\text{O}/\text{H})$, highly unlikely to cause any significant effects. Finally, in interacting systems the central metallicity is lowered by the in-fall of unenriched gas (Michel-Dansac et al., 2008; Ellison et al., 2008; Rupke et al., 2010). This would therefore act in the opposite sense to the result we find. It should also be noted that whilst a study of gas-phase metallicities of the local environments of CCSNe (Anderson et al. MNRAS submitted) finds a trend favouring SNIbc in high-metallicity regions, even the highest metallicity environments seem to host a significant fraction of SNII.

It is also possible that stellar rotation (e.g. Heger et al., 2003) and binarity (e.g. Nomoto et al., 1995) could contribute to this effect. It is not clear why the binary fraction should be higher within the disturbed galaxy sample, but it should be noted that the increased densities within these nuclear starburst regions could lead to more massive and denser clusters, within which processes such as stellar mergers and binary interactions would be more prevalent (e.g. Portegies Zwart et al., 2010).

To conclude, our preferred explanation of this central excess of SNIbc is that the central regions of these disturbed galaxies are hosting starbursts with initial mass functions biased to high stellar masses. Given the small numbers of SNe involved, the uncertain mass limits corresponding to progenitors of different SN types, and the likely role of binarity in determining SN type, it is hard to quantify the implications of this result for the IMF. However, an illustrative calculation can be performed as follows. Under the assumption of a Salpeter IMF, and the (admittedly simplistic) assumptions that CCSNe arise from single stars with masses between 8 and $80 M_{\odot}$ and that mass alone determines SN type, the relative numbers of SNII and Ibc in the outer regions of undisturbed galaxies (2.3:1) indicate a transition at about $18 M_{\odot}$. The apparent inversion of this ratio for the central regions of the disturbed galaxies (0.18:1), if interpreted purely as a change in IMF slope, appears to require a positive index in the IMF slope (formally $x = +0.95$ cf. -1.35 , assuming the transition mass is unchanged at $18 M_{\odot}$). However, we emphasize that this is purely illustrative; all of the assumptions are likely to be in error at some level, and binarity and metallicity effects may play some part in the changes we find.

We note here that we are modifying the conclusions of Anderson & James (2009) in

that it is hard to interpret the previously found central SNIbc excess purely in terms of metallicity effects. However, we note that there is still a marginal central excess of SNIbc in the undisturbed galaxy sample, indicating some effect of metallicity. Quantifying the relative sizes of the different effects will be the focus of future studies.

Finally, it is interesting to note that with current research indicating a connection between gamma ray bursts (GRBs) and type Ic SNe (Woosley & Bloom, 2006), recent studies (e.g. Conselice et al., 2005; Wainwright, 2007; Fryer et al., 2007) have found that GRB host galaxies show an over-abundance of merging or interacting galaxies compared to other star-forming hosts.

5. Conclusions

We have analysed the spatial distribution of 178 CCSNe within a sample of host galaxies with recession velocities less than 6000 km/s. Host galaxies were classified by eye according to whether they show disturbance due to strong tidal interactions or mergers. The main results are as follows:

- CCSNe of all types show a strong degree of central concentration in the disturbed galaxies, probably as a result of nuclear starbursts in these galaxies.
- This central excess is dominated by SNIbc.
- The SNIbc in disturbed galaxies are more centrally concentrated than the H α emission.
- The SNIbc excess cannot easily be explained in terms of metallicity effects, extinction, or central incompleteness of SNe.
- Our preferred explanation of the SNIbc excess is that the central regions of the disturbed galaxies are dominated by nuclear starbursts with IMFs biased towards high mass stars, although metallicity, binarity and stellar rotation may also play a role.

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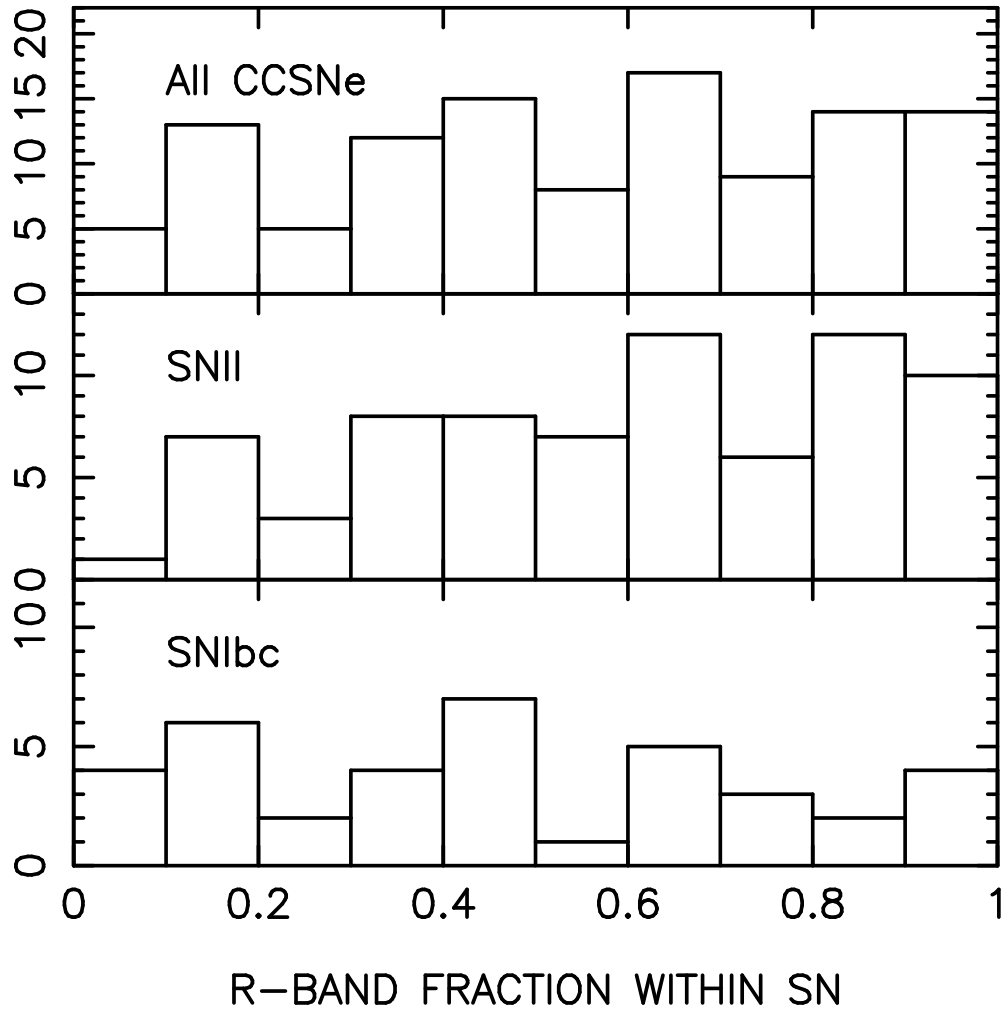


Figure 1. Histogram showing the distribution of fractions of host galaxy R -band light lying within the locations of each CCSN in our undisturbed host galaxies. The top plot represents the distribution of all CCSNe, the middle SNIi and the lower SNIbc.

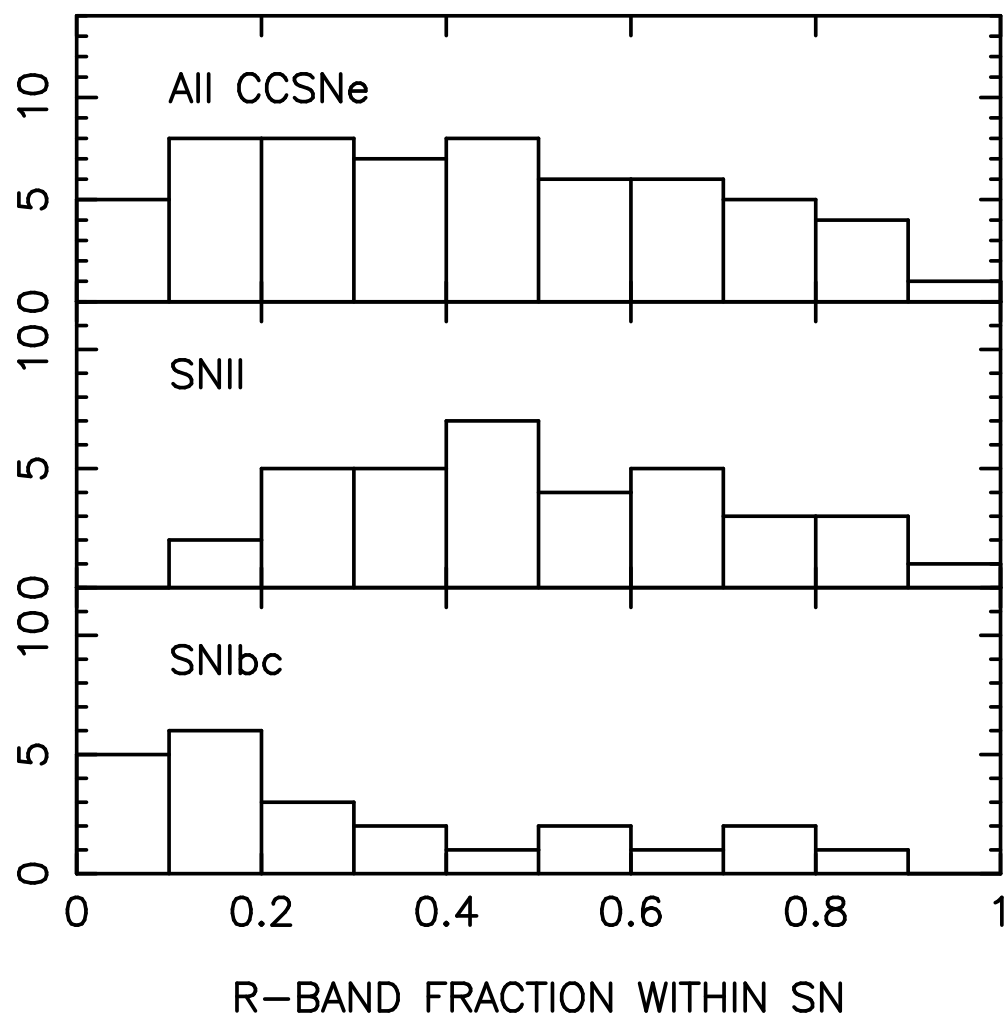


Figure 2. As Figure 1, but for the disturbed host galaxies.

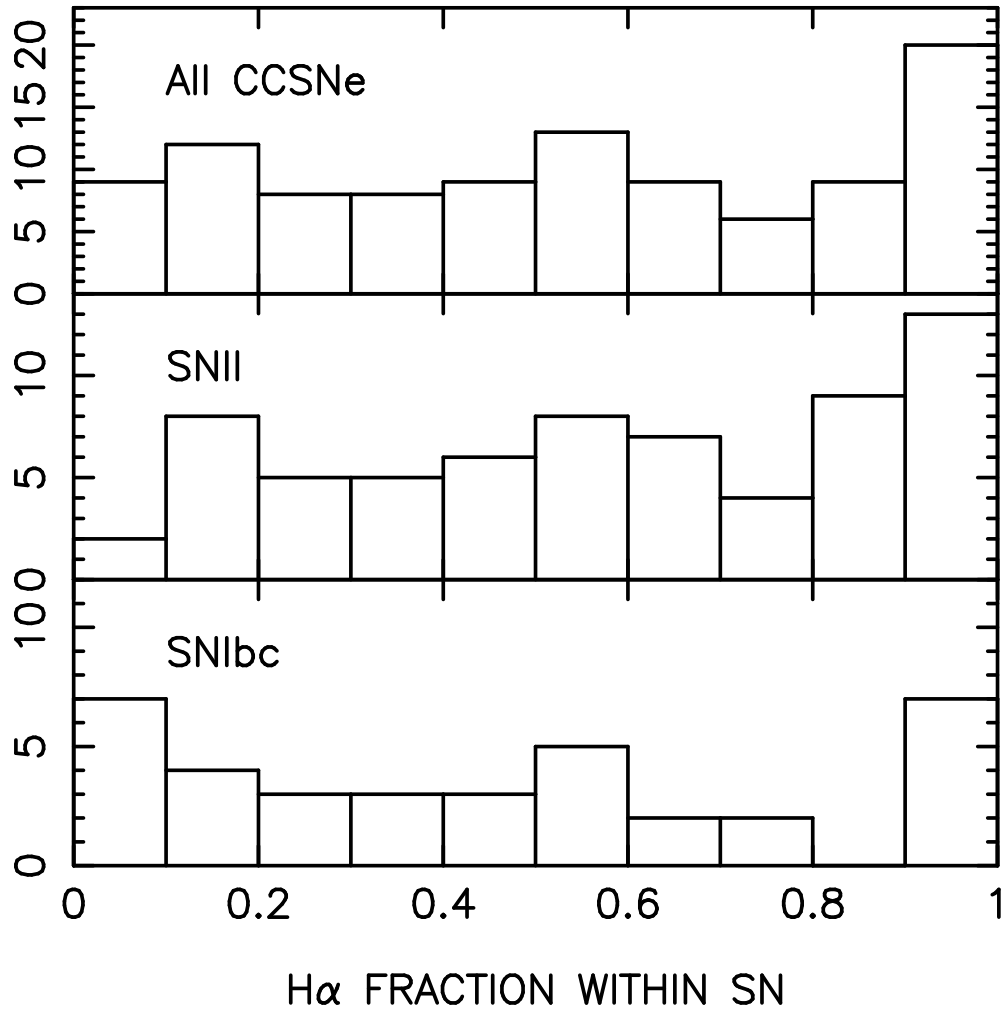


Figure 3. Histogram showing the distribution of fractions of host galaxy H α light lying within the locations of each CCSN in our sample, for the undisturbed host galaxies. Again, the upper plot shows the overall CCSNe distribution, the middle SNIi and the lower SNIbc.

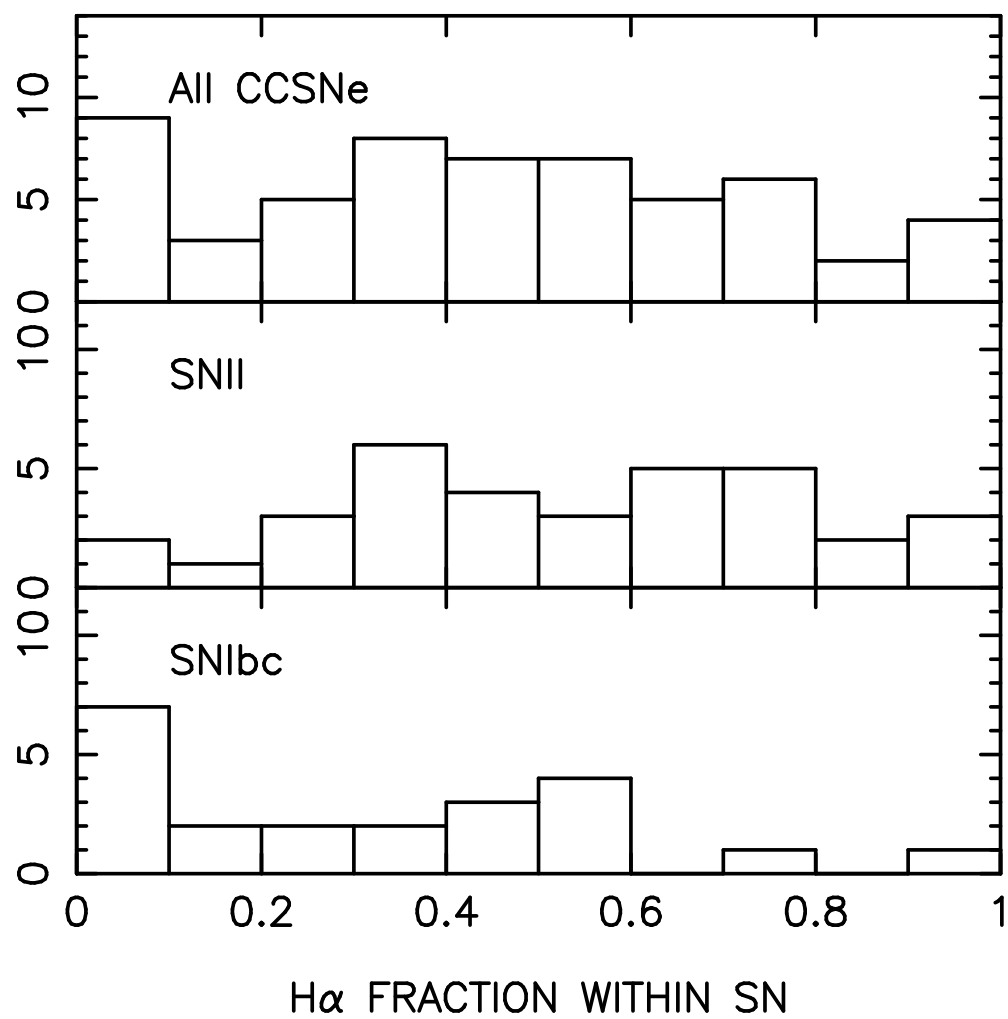


Figure 4. As Figure 3, for the disturbed host galaxies.

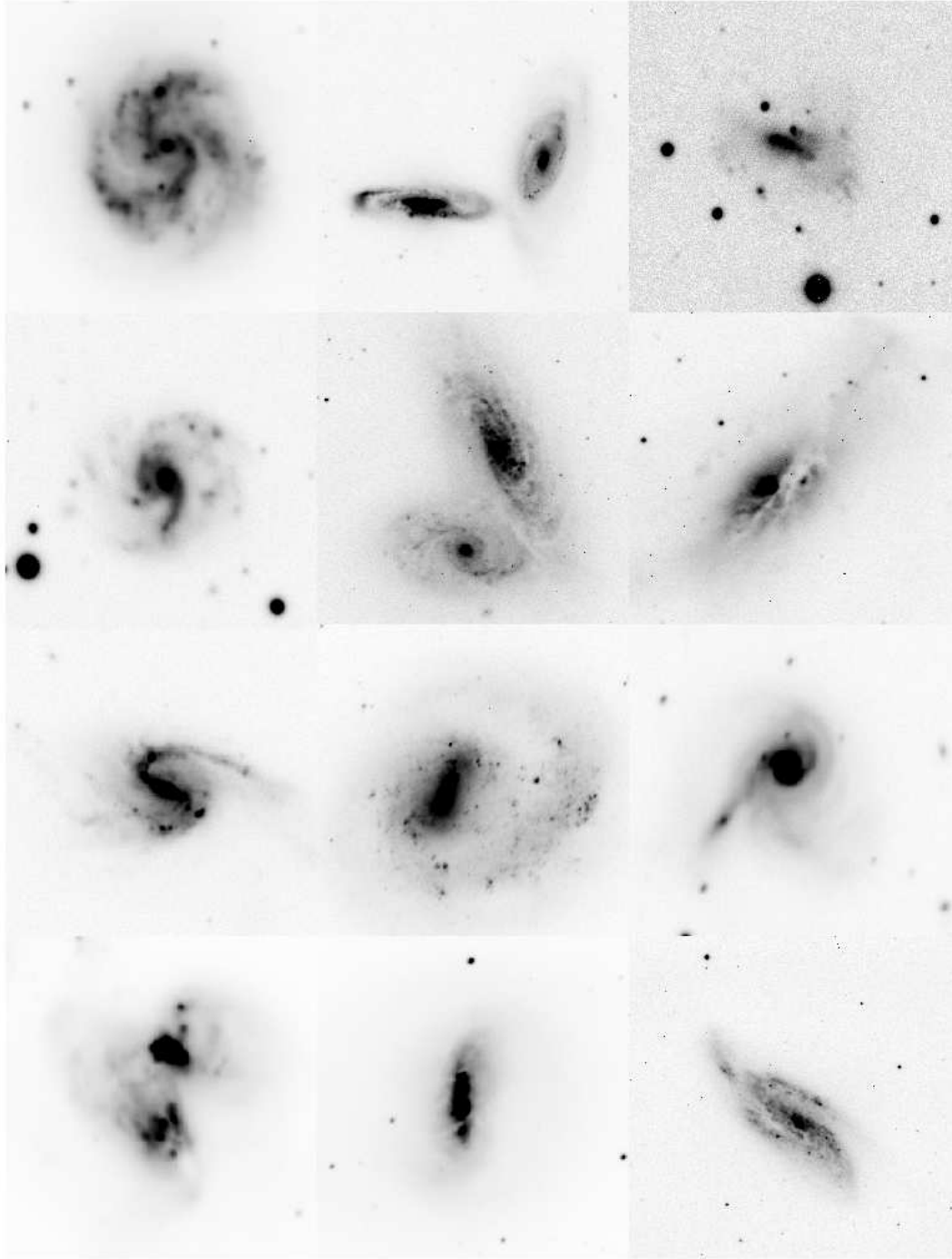


Figure 5. Images of 12 of the host galaxies classified as disturbed and with centrally located CCSNe.

Tables and table captions

Table 1: Undisturbed host galaxy sample used in this analysis. Columns represent the host galaxy, the individual SNe, the spectral classification of the SNe and the fractional R -band light and fractional $H\alpha$ values for each SNe.

Host	SN	SN type	Fr(R)	Fr($H\alpha$)
NGC493	1971S	IIP	0.605	0.570
NGC918	2009js	IIP	0.703	-
NGC941	2005ad	II	0.831	0.864
NGC991	1984L	Ib	0.498	0.401
NGC1035	1990E	IIP	0.272	0.363
NGC1058	1961V	II	0.968	0.931
NGC1058	1969L	IIP	1.000	1.000
NGC1058	2007gr	Ib/c	0.421	-
NGC1073	1962L	Ic	0.754	0.518
NGC1087	1995V	II	0.368	0.497
NGC1187	1982R	Ib	0.695	0.760
NGC1187	2007Y	Ib	0.981	1.000
MCG-01-09-24	2002ei	IIP	0.195	0.195
NGC1343	2008dv	Ic	0.195	0.134
UGC2906	2008im	Ib	0.682	-
UGC2971	2003ig	Ic	0.176	0.108
IC381	2001ef	Ic	0.082	0.052
NGC1832	2004gq	Ib	0.672	0.328
NGC1832	2009kr	II	0.489	-
IC2152	2004ep	II	0.461	0.560
UGC3804	2002A	II _n	0.419	0.253
NGC2551	2003hr	II	0.914	1.000
NGC2596	2003bp	Ib	0.486	0.362
UGC4436	2004ak	II	0.887	0.882
NGC2726	1995F	Ic	0.037	0.050
NGC2742	2003Z	IIP	0.675	0.736
NGC2715	1987M	Ic	0.129	0.044
UGC4904	2006jc	Ib/c	0.332	0.525
NGC2841	1972R	Ib	0.855	0.904
NGC2906	2005ip	II	0.399	0.528
UGC5249	1989C	IIP	0.017	0.058
NGC3074	1965N	IIP	0.110	0.059
NGC3074	2002cp	Ib/c	0.936	0.961
NGC3147	2006gi	Ib	0.984	0.991
NGC3184	1921B	II	0.856	0.954
NGC3184	1937F	IIP	0.808	0.930
NGC3184	1999gi	IIP	0.276	0.112
NGC3198	1966J	Ib	0.898	0.963
NGC3198	1999bw	II _n	0.745	0.755
NGC3240	2001M	Ic	0.323	0.251
NGC3294	1990H	IIP	0.156	0.125
NGC3340	2005O	Ib	0.322	0.305

Host	SN	SN type	Fr(R)	Fr(H α)
NGC3340	2007fp	II	0.170	0.125
NGC3430	2004ez	II	0.788	0.833
NGC3437	2004bm	Ic	0.073	0.076
NGC3451	1997dn	II	0.872	0.946
NGC3504	2001ac	IIn	0.826	0.992
NGC3512	2001fv	IIP	0.669	0.689
NGC3556	1969B	IIP	0.197	0.494
NGC3631	1964A	II	0.915	0.992
NGC3631	1965L	IIP	0.622	0.658
NGC3631	1996bu	IIn	0.923	0.993
NGC3655	2002ji	Ib/c	0.709	0.957
NGC3683	2004C	Ic	0.532	0.545
UGC6517	2006lv	Ib/c	0.480	-
NGC3756	1975T	IIP	0.846	0.856
NGC3810	2000ew	Ic	0.261	0.147
NGC3810	1997dq	Ib/c	0.774	0.734
NGC3949	2000db	II	0.364	0.253
NGC3963	1997ei	Ic	0.197	0.053
NGC4030	2007aa	II	0.942	0.828
NGC4041	1994W	IIn	0.491	0.541
NGC4051	1983I	Ic	0.498	0.473
NGC4051	2003ie	II	0.838	0.885
IC758	1999bg	IIP	0.669	0.657
NGC4136	1941C	II	0.880	0.882
NGC4210	2002ho	Ic	0.146	0.051
NGC4242	2002bu	IIn	0.896	0.930
NGC4303	1926A	IIL	0.607	0.736
NGC4303	1961I	II	0.697	0.877
NGC4303	1964F	II	0.189	0.106
NGC4303	1999gn	IIP	0.418	0.429
NGC4303	2006ov	IIP	0.418	0.429
NGC4303	2008in	IIP	0.845	-
NGC4369	2005kl	Ic	0.271	0.540
NGC4384	2000de	Ib	0.087	0.140
NGC4451	1985G	IIP	0.138	0.212
NGC4559	1941A	IIL	0.208	0.131
UGC7848	2006bv	IIn	0.579	-
NGC4666	1965H	IIP	0.324	0.198
NGC4708	2003ef	II	0.335	0.352
NGC4725	1940B	IIP	0.675	0.802
NGC4900	1999br	IIP	0.786	0.932
NGC4961	2005az	Ic	0.426	-
NGC4981	2007C	Ib	0.320	0.236
NGC5012	1997eg	IIn	0.503	0.449
NGC5033	1950C	Ib/c	0.972	1.000
NGC5033	1985L	IIL	0.585	0.571
NGC5334	2003gm	IIn	0.480	-
NGC5371	1994Y	IIn	0.355	0.212
NGC5468	2002ed	IIP	0.811	0.791

Host	SN	SN type	Fr(R)	Fr(H α)
NGC5559	2001co	Ib/c	0.618	0.497
NGC5584	1996aq	Ic	0.178	0.086
NGC5630	2005dp	II	0.534	0.590
NGC5630	2006am	II _n	0.604	0.617
NGC5673	1996cc	II	0.924	0.934
NGC5668	2004G	II	0.657	0.595
NGC5775	1996ae	II _n	0.757	0.671
NGC5806	2004dg	IIP	0.484	0.378
NGC5850	1987B	II _n	0.995	-
NGC5879	1954C	II	0.615	0.511
NGC5921	2001X	IIP	0.579	0.369
NGC6118	2004dk	Ib	0.673	0.626
NGC6207	2004A	IIP	0.729	0.660
UGC10862	2004ao	Ib	-	0.215
NGC6643	2008ij	IIP	0.519	0.620
NGC6643	2008bo	Ib	0.451	0.510
NGC6700	2002cw	Ib	-	0.642
NGC6946	2004et	II	0.975	-
NGC6951	1999el	II _n	0.320	0.259
UGC11861	1995ag	II	0.343	0.170
UGC11861	1997db	II	0.633	0.396
UGC12160	1995X	II	0.564	0.484
UGC12182	2006fp	II _n	1.000	1.000

Table 2: Disturbed host galaxy sample used in this analysis. Columns represent the host galaxy, the individual SNe, the spectral classification of the SNe and the fractional R -band light and fractional $H\alpha$ values for each SNe, as in table 1.

Host	SN	SN type	Fr(R)	Fr($H\alpha$)
NGC895	2003id	Ic	0.524	-
UGC2984	2002jz	Ic	0.091	0.099
NGC1614	1996D	Ic	0.275	-
NGC1637	1999em	IIP	0.276	0.268
IC391	2001B	Ib	0.062	0.060
NGC1961	2001is	Ib	-	0.749
NGC2207	1999ec	Ib	-	0.521
NGC2207	2003H	Ib	-	0.259
NGC2146	2005V	Ib/c	0.033	0.091
ESO492-G2	2005lr	Ic	-	0.005
UGC3829	2001ej	Ib	0.152	0.391
NGC2276	1968V	II	0.699	0.790
NGC2276	2005dl	II	0.247	0.099
NGC2276	1993X	II	0.899	0.619
NGC2532	1999gb	IIIn	0.485	0.443
NGC2532	2002hm	Ic	0.023	0.011
NGC2604	2002ce	II	0.381	0.560
NGC2782	1994ak	IIIn	0.725	0.977
NGC2993	2003ao	IIP	0.456	0.784
NGC3169	1984E	IIL	0.684	0.731
NGC3310	1991N	Ic	0.268	0.277
NGC3323	2004bs	Ib	0.191	0.119
NGC3323	2005kk	II	0.766	0.875
NGC3367	1992C	II	0.689	0.687
NGC3367	2007am	II	0.302	0.314
NGC3627	1973R	IIP	0.471	0.566
NGC3627	1997bs	IIIn	0.362	0.348
NGC3627	2009hd	II	0.496	-
NGC3690	1993G	IIL	0.464	0.744
NGC3690	1998T	Ib	0.056	0.056
NGC3690	1999D	II	0.560	0.849
NGC3786	1999bu	Ic	0.180	0.522
NGC3811	1971K	IIP	0.809	0.900
IC2973	1991A	Ic	0.742	0.588
NGC4038	2004gt	Ib/c	0.834	0.991
NGC4088	1991G	IIP	0.466	0.453
NGC4088	2009dd	II	0.100	-
NGC4141	2008X	IIP	0.194	0.085
NGC4141	2009E	IIP	0.594	0.491
NGC4254	1967H	II	0.664	0.648
NGC4254	1972Q	IIP	0.811	0.791
NGC4254	1986I	IIP	0.334	0.318
NGC4273	2008N	IIP	0.300	0.316
NGC4273	1936A	IIP	0.569	0.598
NGC4490	1982F	IIP	0.277	0.202

Host	SN	SN type	Fr(R)	Fr(H α)
NGC4568	1990B	Ic	0.302	-
NGC4568	2004cc	Ic	0.158	-
NGC4618	1985F	Ib	0.121	0.087
NGC4615	1987F	IIn	0.489	0.333
NGC4688	1966B	IIL	0.571	0.454
NGC4691	1997X	Ic	0.171	0.472
NGC5000	2003el	Ic	0.482	0.476
NGC5021	1996ak	II	0.619	0.659
MCG-04-32-07	2003am	II	0.211	0.339
NGC5194	1994I	Ic	-	0.122
NGC5194	2005cs	IIP	-	0.222
NGC5395	2000cr	Ic	0.538	0.549
NGC5480	1988L	Ib	0.230	0.369
NGC5682	2005ci	II	0.204	0.191
NGC7479	1990U	Ic	0.603	0.488
NGC7479	2009jf	Ib	0.764	-
NGC7537	2002gd	II	0.759	0.685
NGC7714	2007fo	Ib	0.377	-
UGC12846	2007od	IIP	0.945	1.000

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